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PTO/SB/05 (12/97)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b)

Attorney Docket No. 80398.P350 Total Pages 2

First Named Inventor or Application Identifier Ted J. Cooper

Express Mail Label No. EL672752346US

ADDRESS TO: **Assistant Commissioner for Patents**
Box Patent Application
Washington, D. C. 20231

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

1. X Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)

2. X Specification (Total Pages 23)
(preferred arrangement set forth below)
- Descriptive Title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claims
- Abstract of the Disclosure

3. X Drawings(s) (35 USC 113) (Total Sheets 10)

4. X Oath or Declaration (Total Pages 4)

a. X Newly Executed (Original or Copy)

b. ___ Copy from a Prior Application (37 CFR 1.63(d))
(for Continuation/Divisional with Box 17 completed) **(Note Box 5 below)**

i. ___ DELETIONS OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

5. ____ Incorporation By Reference (useable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. ____ Microfiche Computer Program (Appendix)

7. ____ Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
a. ____ Computer Readable Copy
b. ____ Paper Copy (identical to computer copy)
c. ____ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. __X__ Assignment Papers (cover sheet & documents(s))

9. ____ a. 37 CFR 3.73(b) Statement (where there is an assignee)

__X__ b. Power of Attorney

10. ____ English Translation Document (if applicable)

11. ____ a. Information Disclosure Statement (IDS)/PTO-1449

____ b. Copies of IDS Citations

12. ____ Preliminary Amendment

13. __X__ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)

14. ____ a. Small Entity Statement(s)

b. Statement filed in prior application, Status still proper and desired

15. ____ Certified Copy of Priority Document(s) (if foreign priority is claimed)

16. __X__ Other: Certificate of Express Mail with copy of postcard showing contents of Express Mail package.

17. **If a CONTINUING APPLICATION,** check appropriate box and supply the requisite information:

____ Continuation ____ Divisional ____ Continuation-in-part (CIP)

of prior application No: _____

18. **Correspondence Address**

____ Customer Number or Bar Code Label _____
(Insert Customer No. or Attach Bar Code Label here)

or

__X__ Correspondence Address Below

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FEE TRANSMITTAL FOR FY 2001

TOTAL AMOUNT OF PAYMENT ($) 830.00

Complete if Known:
Application No. Not yet assigned
Filing Date Herewith
First Named Inventor Ted J. Cooper
Group Art Unit Not yet assigned
Examiner Name Not yet assigned
Attorney Docket No. 80398.P350

METHOD OF PAYMENT (check one)

1. [X] **The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:**

Deposit Account Number 02-2666
Deposit Account Name

[X] **Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17**

2. X **Payment Enclosed:**
X **Check**
____ **Money Order**
____ **Other**

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	710	201	355	Utility application filing fee	710.00
106	320	206	160	Design application filing fee	
107	490	207	245	Plant filing fee	
108	710	208	355	Reissue filing fee	
114	150	214	75	Provisional application filing fee	

SUBTOTAL (1) $ 710.00

2. EXTRA CLAIM FEES

		Extra Claims		Fee from below		Fee Paid
Total Claims	20	– 20** =		X 18.00	=	
Independent Claims	4	– 3** =	1	X 80.00	=	80.00
Multiple Dependent					=	

**Or number previously paid, if greater; For Reissues, see below.

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	80	202	40	Independent claims in excess of 3
104	270	204	135	Multiple dependent claim, if not paid
109	80	209	40	**Reissue independent claims over original patent
110	18	210	9	**Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) $ 80.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for response within first month	
116	390	216	195	Extension for response within second month	
117	890	217	445	Extension for response within third month	
118	1,390	218	695	Extension for response within fourth month	
128	1,890	228	945	Extension for response within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive unavoidably abandoned application	
141	1,240	241	620	Petition to revive unintentionally abandoned application	
142	1,240	242	620	Utility issue fee (or reissue)	
143	440	243	220	Design issue fee	
144	600	244	300	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	40.00
146	710	246	355	For filing a submission after final rejection (see 37 CFR 1.129(a))	
149	710	249	355	For each additional invention to be examined (see 37 CFR 1.129(b))	
179	710	279	355	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) _____

Other fee (specify) _____

SUBTOTAL (3) $ 40.00

*Reduced by Basic Filing Fee Paid

SUBMITTED BY:

Typed or Printed Name: Sang Hui Michael Kim

Signature: Sang Hui K Date: 10/24/00

Reg. Number: 40,450 Telephone Number: _____

Attorney Docket No.: 80398.P350 *PATENT*

UNITED STATES PATENT APPLICATION

For

METHOD AND APPARATUS TO PROVIDE EDGE ENHANCEMENTS AS PART OF A DEMOSAICING PROCESS

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METHOD AND APPARATUS TO PROVIDE EDGE ENHANCEMENTS AS PART OF A DEMOSAICING PROCESS

FIELD OF THE INVENTION

The present invention relates generally to image processing and image processing devices. More particularly, the present invention relates to a method and apparatus to provide edge enhancements as part of a demosaicing process.

BACKGROUND OF THE INVENTION

A common image processing device is a digital still camera (DSC). A DSC is an image input device that typically includes a single charge-couple device (CCD) array. A CCD array is an array of light detectors, which typically detects one of three monochrome colors (e.g., red R, green G, or blue B) for each light detector location. To output a color image, however, the DSC must provide a complete set of RGB (or CMY or YC_rC_r) tri-stimulus values for each light detector location. Such a process is commonly referred to as "demosaicing" in which full color at every pixel is calculated from a patchwork of color filter values distributed over the captured image.

Thus, a typical image processing workflow for a current DSC is to capture an image using the CCD array of light detectors, to convert the information from the light detectors into digital form (i.e., raw captured image data), and to provide color to image data by a demosaicing process, to perform a white balancing process, to perform a chromatic improvement process, and finally to perform an edge enhancement process.

In the image capturing process, prior to demosaicing, a DSC arranges the colors from the light detectors in a systematically repeating pattern as the raw captured image data. For example, the raw captured image data can have "Bayer" pattern with interleaved lines of "RGRGRG..." followed by lines of "GBGBGB..." At this point, the

captured image is represented as a mosaic of RGB color primaries for each light detector location in which no color can be viewed.

Demosaicing is thus the process of computing a complete set of tri-stimulus values at every CCD light detector location to provide color to the image. A number of algorithms can be used to compute the complete set of values, which typically involve nearest neighbor substitution, bi-linear interpolation, and median filtering. For example, a pixel or light detector location, which corresponds to a green detector can infer from neighboring detectors what red and blue values should be at that location where the green detector is located. Similarly, a pixel that corresponds to a red detector can infer from neighboring detectors what the green and blue values are at that location.

A limitation with the demosaicing process, which is equivalent to low-pass filtering process, is that it has some inherent side effects. For example, a low-pass filtering process attenuates the high-frequency detail or accentuates the low-frequency detail of an image. Thus, a common side effect is that it introduces chromatic fringing at the edges of sharp contrast boundaries in an image. That is, the edges of the sharp contrast boundaries have red and blue fringe artifacts. **FIG. 1** shows an image 100 having such red and blue artifacts referenced by numerals 101 and 103, respectively.

Currently, the DSC industry uses various forms of edge enhancement processes to improve an image. An edge enhancement process is used to detect edges in an image and to increase the edge detail of the image to produce a more realistic and sharper image in keeping with certain aspects of the Human Visual System (HVS). Such a process, however, compounds the problem of the red and blue fringe artifacts because the edge enhancement typically causes the magnitude of the color fringing to increase in direct proportion to the intensity of the enhancement.

Furthermore, a disadvantage with the operation of a current DSC is that edge enhancements occur at the end of the image processing workflow, i.e., after white balancing and chromatic enhancement processes. White balancing is a process used to calibrate the proportion of red, green, and blue color values so that the white color in the image results in a pure white color without color casts. Chromatic enhancement is a process used to provide a deeper or more saturated color to the color image. Both of these processes, however, alter the raw captured image data before the edge enhancements can take place.

Consequently, a great deal of spatial and chromatic information originally present in the raw image data may have been before the edge enhancement process could have access to the data. This may cause low color fidelity and degraded edge sharpness. For example, as illustrated in **FIG. 1**, an exemplary image 100 is shown in which edge enhancements are performed late in an image processing workflow in accordance with prior art.

Referring to **FIG. 1**, image 100 shows a number "2," which is greatly magnified for purposes of illustration. Blue and red pixel alternations can be noticed by reference to numberals 101 and 103 in image 100 along the number "2." Such alternations are commonly referred to as a "chromatic moiré." The chromatic moiré is greatly exaggerated because edge enhancements occur late in the image data processing workflow thus causing the image to have low color fidelity and degraded edge sharpness.

SUMMARY OF THE INVENTION

According to one aspect of the invention, an image processing method is disclosed in which an image is captured and edge enhancements are provided to the captured image as part of a demosaicing process.

Other features and advantages of the present invention will be apparent from the accompanying drawings, and from the detailed description, which follows below.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present invention are illustrated by way of example and not intended to be limited by the figures of the accompanying drawings, in which like references indicate similar elements and in which:

FIG. 1 depicts an exemplary image in which edge enhancements are performed late in an image processing workflow in accordance with prior art.

FIG. 2 depicts an exemplary image processing system in which the present invention can be implemented;

FIG. 3 depicts a flow chart illustrating an image processing operation according to one embodiment;

FIG. 4 depicts a flow chart illustrating post demosaicing processing according to one embodiment;

FIG. 5 depicts a flow chart illustrating a detailed operation for providing edge enhancements as part of the demosaicing process of **FIG. 3** according to one embodiment;

FIG. 6A depicts an exemplary schematic image based on raw data;

FIG. 6B depicts an exemplary schematic gray map image;

FIG. 6C depicts an exemplary high contrast masked edge for a mask image;

FIG. 6D depicts an exemplary image with unsharp edge enhancement;

FIG. 6E depicts an exemplary luminance graph of a cross-sectional view of the image of **FIG. 6D**;

FIG. 6F depicts an exemplary schematic image with multiplicative blending;

FIG. 6G depicts an exemplary image in which edge enhancments are provided as part of a demosaicing process;

FIG. 7 depicts a flow chart illustrating an operation for a creating mask image from a fringe corrected image according to one embodiment;

FIG. 8A depicts an exemplary a 5 x 5 pixel pattern with the central pixel being a part of the edge of an image; and

FIG. 8B depicts an exemplary L**a***b** color space chart.

DETAILED DESCRIPTION

According to the embodiments described herein, a method and apparatus are described in which an image is captured and edge enhancements are provided to the captured image as part of a demosaicing process. By providing edge enhancements as part of the demosaicing process, significant improvements in color fidelity and edge sharpness are possible because the edge enhancement process has access to unaltered spatial and chromatic information contained in the raw captured image data.

FIG. 2 depicts an exemplary image processing system 200 in which the present invention can be implemented. The image processing system 200 can represent any number of image processing devices such as, for example, an electronic camera, video camera, or a digital still camera (DSC), and is not intended to be limited to any particular image processing device.

Referring to **FIG. 2,** image processing system 200 includes a charge-couple device (CCD) array 210, an analog/digital (A/D) converter 220, memory storage 230, processor 240, and output 250. The CCD array 210 is coupled to the A/D converter 220. The A/D converter 220 is coupled to the memory storage 230. The processor 240 and output 250 are coupled to the memory storage 230.

CCD array 210 is an image detector having an array of light detectors. The CCD array 210 is only one type of image detector that may be used, however, other alternative image detectors can be used. For example, phototransistors, photodiodes, or any other form of photo capture device can be use as an image detector. CCD array 210 acquires raw image data using the array of light detectors. For one embodiment, CCD array 210 detects red R, green G, and blue B color primaries and arranges the color primaries in a repeating pattern such as, for example, a "Bayer" pattern, as "raw captured image data."

For an alternative embodiment, CCD array 210 detects cyan-magenta-yellow-green (CMYG) color primaries and arranges the color primaries in a repeating pattern as the raw captured image data.

A/D converter 220 is a processing device that converts analog signals into digital signals. A/D converter 220 receives image information from the CCD array 210 as analog signals and converts them into digital signals. The digital signals representing the captured image are stored in memory storage 230 as the raw image data.

Memory storage 230 is a memory device to store data or information. Memory storage 230 can be a random access memory (RAM), flash memory, or other like memory devices. For alternative embodiments, memory storage 230 can include a plurality of memory devices. Memory storage 230 stores image data or information from the CCD array 210 and A/D converter 220. Alternatively, memory storage 230 can also store instructions to be processed by processor 240 to perform image processing operations on image data. Furthermore, memory storage 230 can provide short-term and long-term storage of image data for processing, display, and archival purposes.

Processor 240 is a processing device such as a high-speed microprocessor. Processor 240 can access memory storage 230 and process image data stored therein. For one embodiment, processor 240 processes raw image data stored in memory storage 230 and provides edge enhancements to the raw image data as part of a demosaicing process as will be described in further detail below. Processor 240 can also store the edge enhanced image back in memory storage 230. Furthermore, processor 240 can cause the edge enhanced image to be sent to output 250 or to be further processed.

Output 250 can be a display device such as, for example, a liquid crystal display (LCD) or other like display device. Alternatively, output 250 can be another storage

device or a data compression device. Furthermore, output 250 can be an interface to an external or remote device in which image data is displayed or provided to the external or remote device. Output 250 can also output information or data to the external or remote device by a direct connection or a network connection.

The image processing techniques described herein can be implemented by hardware and/or software contained within image processing system 200. For example, image processor 240 can execute code or instructions stored in a machine-readable medium, e.g., memory storage 230, to perform the operations as described in **FIGS. 3**, **4**, **5**, and **7**.

The machine-readable medium may include a mechanism that provides (i.e., stores and/or transmits) information in a form readable by a machine such a processor, computer, or a digital processing device. For example, a machine-readable medium may include a read only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, or flash memory devices. The code or instructions can be represented by carrier wave signals, infrared signals, digital signals, and by other like signals.

FIG. 3 depicts a flow chart illustrating an image processing operation 300 according to one embodiment. The operation 300 illustrates combining "demosaicing" and edge enhancement in the same process.

For purposes of explanation, operation 300 begins at operation 310. Referring to **FIG. 3**, at operation 310, an image is captured. For example, the CCD array 210 can capture an image using an array of light detectors. The captured image can be stored in memory storage 230 as raw image data in a Bayer pattern. Alternatively, the raw image data can be captured in other patterns.

At operation 350, edge enhancements are provided to the captured image as part of a demosaicing process. For example, processor 240 can process the raw image data stored in memory storage 230 to provide edge enhancements as part of a demosaicing process such as that explained with regards to **FIG. 5**. Alternatively, any form of edge enhacnement process can be used for operation 300 such that it is performed as part of demosaicing.

By providing edge enhancements early in an image processing workflow, (i.e., as part of the demosaicing process), there can be significant improvements in color fidelity and edge sharpness because the edge enhancement process has access to unaltered spatial and chromatic information contained in the raw captured image data.

FIG. 4 depicts a flow chart illustrating post demosaicing processing according to one embodiment. The following operations shown in **FIG. 4** can be performed after operation 350 of **FIG. 3**. Alternatively, the following operations can be optional.

Referring to **FIG. 4**, at operation 360, a post demosaicing process can be performed. For example, processes to further improve the image and color can be performed such as white balancing or chromatic improvement. Alternatively, the demosaiced image can be compressed to be stored in memory storage 230.

At operation 370, the processed color image can be output to a user via a visual display. Alternatively, the color image can be output to a storage device for storage. The color image can also be output to external and remote devices either by a direct connection or a network connection.

FIG. 5 depicts a flow chart illustrating the detailed operation 350 for providing edge enhancements as part of the demosaicing process of **FIG. 3** according to one embodiment. The operation 350 not only provides edge enhancement, but also

demosaicing. Thus, operation 350 illustrates an operation that provides edge enhancements as part of a demosaicing process. For purposes of explanation, operation 350 begins at operation 510.

Referring to **FIG. 5**, at operation 510, a gray map (or brightness map) using the raw captured image data (e.g., RGB data) is created. **FIG. 6A** depicts an exemplary schematic image based on raw data. A demosaicing process may be employed to extract a first order approximation for the R, G, and B pixel values of the raw data to create a gray map (e.g., bi-linear interpolation). The gray map is an image composed of gray-level brightness. **FIG. 6B** depicts an exemplary schematic gray map image. It should be noted that attempts using a simplified luminance approximation for the gray map found in Equation (1) below failed noticeably if chromatic edges are present.

$$Luminance = 0.177*R + 0.813*G + 0.011*B \ [failed] \qquad (1)$$

Instead, a luminance based on L*a*b* is much more robust. However, it is not required to use the full CIE L* calculation. The L*a*b* is one way to represent colors in color space, in which L* represents brightness, and a* and b* define chromatic axes. The luminance based on L*a*b* is used because it provides a perceptually uniform color space. The RGB data can easily be converted to L*a*b* values for some assume image white point.

At operation 520, the gray map image is stored. For example, the gray map image such as that shown in **FIG. 6B** can be stored in storage memory 230.

At operation 530, a mask image is created, which is formed by detecting edges in the gray map and providing enhancements to the edged. The edge detection/enhancement process is discussed in further detail in **FIG. 7**. For one embodiment, the pixels of the

mask image are different from the original image located in strong brightness gradient areas. The final "color" of each changed pixel is either a maximum or minimum form the pixels that surround it. It should be noted that any form of edge enhancement can be used in this invention. Current methods include unsharp masking, zero-crossing gradient detection, chromatic discontinuity, and various kernel transforms. The use of the mask technique described here is just one embodiment of the edge enhancement process.

FIG. 6C depicts an exemplary high contrast masked edge for a mask image. For one embodiment, **FIG. 6C** may illustrate the mask image generated from **FIG. 6B**. Although no color is shown in **FIG. 6C**, the mask image can have fewer colors and more smoothly varying colors than the original image. Moreover, the visibility of the textual edges is more pronounced and lacks the chromatic moiré around the slanted edges of the text. This can have the affect of providing a block-like appearance.

At operation 540, unsharp edge enhancement is performed on the mask image. That is, the block-like structured edges are smoothed by an unsharp edge enhancement process, which changes the luminance level to accentuate the edge transition contrast of an image. Also, because the mask image has strong visual steps in its contour, it typically needs to be smoothed by adding a fractional part of the original demosaiced image to it. **FIG. 6D** depicts an exemplary image with an unsharp edge enhancement, and **FIG. 6E** depicts an exemplary luminance graph of a cross-sectional view of the image of **FIG. 6D**.

At operation 550, multiplicative blending is performed to obtain the final output. For example, a blending process based on the formula (2) below can be performed to obtain the desired output.

$$Output = Mask * (1-\alpha) + Original * \alpha \qquad (2)$$

This blending process yields the original demosaiced RGB values everywhere except where strong gradients were found. **FIG. 6F** shows an exemplary image with the multiplicative bending. The optimal value of α depends on use for the image. For example, if soft smooth edges necessary, then larger values of α are preferred. Furthermore, for images with small text or fine jewelry, smaller values of α are preferred.

For one embodiment, **FIG. 6D** and **FIG. 6A** or **6B** may be blended multiplicatively to obtain the final image. **FIG. 6G** depicts an exemplary final output image in which edge enhancement was provided during a demosaicing process. By way of contrast to **FIG. 1** in which edge enhancement is performed at the end of an image processing workflow, **FIG. 6G** shows significant improvement in color fidelity and edge sharpness. This is a result of performing edge enhancement as part of the demosaicing process.

FIG. 7 depicts a flow chart illustrating the detailed operation 530 of **FIG. 5** to create a mask image by performing edge detection/enhancement. The operation 530 uses the knowledge of the edge location to sharpen the edges of an image in a non-linear way to produce contrast enhancement. For purposes of explanation, operation 530 begins at operation 710.

At operation 710, an NxN pixel neighborhood of a central pixel, which is part of a detected edge, is investigated. To determine the central pixel, a threshold criteria is applied. For example, a threshold criteria is applied to each pixel to determine if it is involved in a significant brightness change compared to its neighbors. Exemplary values for the threshold range from 20-35 units based on an 8-bit monochrome image scale (after

the gray image has been created). Thus, once the central pixel is determined to have passed the threshold criteria, the operation investigates the NxN pixel neighborhood.

The central pixel (each of the pixels that are determined as a part of the edges) is examined in terms of a localized matrix or cell of pixels that surround the pixel in question in a square array whose size is N pixels wide by N pixels high. Exemplary values of N can be odd numbers, such as 3, 5, 7... to *N*. However, a 5 x 5 pixel is preferred because it calculates in all the standard compass directions without overwhelming the image processing device's performance. **FIG. 8A** illustrates schematically a 5 x 5 pixel with the central pixel being a part of the edge of an image.

At operation 720, each of the twenty-four pixels in the neighborhood of the central pixel is ranked based on its brightness and perceptual color values. To rank each pixel, L**a***b** values are used. The L**a***b** values can be converted from RGB values mathematically.

FIG. 8B shows an L**a***b** color space chart divided into multiple bins to classify the color values for each pixel. For one embodiment, the chart is divided into eight bin spaces, but the chart can be divided more than eight bins for greater accuracy. The *a** axis runs from green (+*a**) to magenta (-*a**), and the *b** axis runs from yellow (+*b**) to blue (-*b**).

The chart is further divided into two regions - a first region, which is anywhere in between +4 units and –4 units (based on 8-bit storage values for a* and b*) on either the *a** or *b** axis (shaded region in **FIG. 8A**), and a second region that is anywhere outside of the first region. The color values of the first region are neutral and any pixel that falls within the first region are grouped and handled separately than any pixel that falls within the second region. The pixels whose chromaticity (color amount) fall within the radius of

+ or – 4 units in the a* and b* axis are basically neutral colors and are excluded from further processing in determining the chromatic content of the neighborhood around the central pixel.

At operation 730, as for the pixels that fall within in the second region, each of the twenty-four pixels is determined to be in first and second most popular color groups. This determination is based within the eight bin spaces according to its a^*,b^* value.

At operation 740, the average brightness of each of first and second color groups is determined. At operation 750, a test is applied to compare the central pixel brightness, which passed the threshold criteria, against the first and second popular color groups. The process checks to see if the central pixel's brightness is closer to the first most popular color group.

At operation 760, if the central pixel's brightness is closer to the first most popular color group, then the color values for the first most popular color group are stored in the RGB values of central pixel in question.

At operation 770, if the central pixel's brightness is not closer to the first most popular color group's average brightness (i.e., the central pixel's brightness is closer to the second most popular color group's average brightness), then that second most popular color group's color values are stored into the RGB value for the central pixel. However, the brightness of the central pixel is kept with its original L* value.

At operation 780, the operations 710 to 770 are repeated until all the detected edges are processed. Thus, edge detection and enhancement are provided as part of the demosaicing process.

For any neighborhood pixel that falls within the first region, it is grouped separately and handled as though they are their own separate groups. For any other pixel

in the image that is not involved in edges, the original first order demosaiced RGB values are used.

The final image of the above operations in **FIGS. 5** and **7** can be illustrated by image 600 of **FIG. 6G** in which edge enhancement are provided as part of a demosaicing process. By creating a mask image in the above manner, the final image can be more chromatically accurate and spatially correct because edge detection and enhancement are provided as part of the demosaicing process

Thus, a method and apparatus to provide edge enhancement during a demosaicing process have been described. In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

CLAIMS

What is claimed is:

1. An image processing method comprising:

capturing an image; and

providing edge enhancements to the captured image as part of a demosaicing process.

2. The method of claim 1, further comprising:

performing post demosaicing processing on the captured image; and

outputting the processed image.

3. The method of claim 1, wherein providing the edge enhancements includes:

creating a brightness map of the captured image.

4. The method of claim 3, wherein providing the edge enhancements further includes:

detecting edges of the captured image using the brightness map;

creating a mask image form the edge detected brightness map; and

performing unsharp edge enhancement from the masked image.

5. The method of claim 4, wherein providing the edge enhancements further includes:

blending multiplicatively the unsharp edge enhanced image with the brightness map.

6. An apparatus comprising:

an image capturing device to capture an image; and

a processor to provide edge enhancements to the captured image as part of a demosaicing process.

7. The apparatus of claim 6, wherein the processor is to perform post demosaicing processing on the captured image and to output the processed image.

8. The apparatus of claim 6, wherein the processor is to create a brightness map of the captured image.

9. The apparatus of claim 8, wherein the processor is to detect edges of the captured image using the brightness map, to create a mask image form the edge detected brightness map, and to perform unsharp edge enhancement from the masked image.

10. The apparatus of claim 9, wherein the processor is to blend multiplicatively the unsharp edge enhanced image with the brightness map.

11. A machine-readable medium that provides instructions, which if executed by a processor, cause the processor to perform the operations comprising:

capturing an image; and

providing edge enhancements to the captured image as part of a demosaicing process.

12. The machine-readable medium of claim 11, further providing instructions, which if executed by the processor, cause the processor to perform the operations comprising:

performing post demosaicing processing on the captured image; and

outputting the processed image.

13. The machine-readable medium of claim 11, further providing instructions, which if executed by the processor, cause the processor to perform the operations comprising:

creating a brightness map of the captured image.

14. The machine-readable medium of claim 13, further providing instructions, which if executed by the processor, cause the processor to perform the operations comprising:

detecting edges of the captured image using the brightness map;

creating a mask image form the edge detected brightness map; and

performing unsharp edge enhancement from the masked image.

15. The machine-readable medium of claim 14, further providing instructions, which if executed by the processor, cause the processor to perform the operations comprising:

blending multiplicatively the unsharp edge enhanced image with the brightness map.

16. An image processing device comprising:

an image capturing unit to capture an image;

a memory device to store the captured image;

an output unit coupled to the memory device; and

a processor to provide edge enhancements to the captured image in the memory device as part of a demosaicing process and to cause the enhanced image to be output is to the output unit.

17. The image processing device of claim 16, wherein the image capturing unit includes a charge-couple device (CCD) array, phototransistors, or photodiodes.

18. The image processing device of claim 16, wherein the output unit is a display device.

19. The image processing device of claim 18, wherein the processor is to perform post demosaicing processing on the captured image and to cause the image to be output to the display device.

20. The image processing device of claim 19, wherein the post demosaicing processing is a white balancing processing or a chromatic improvement processing.

ABSTRACT OF THE DISCLOSURE

A method and apparatus to provide edge enhancements as part of a demosaicing process are disclosed in which an image is captured, and edge enhancements are provided to the captured image as part of a demosaicing process. By providing edge enhancements as part of the demosaicing process, significant improvements in color fidelity and edge sharpness are possible because the edge enhancement process has access to unaltered spatial and chromatic information contained in the raw captured image data.

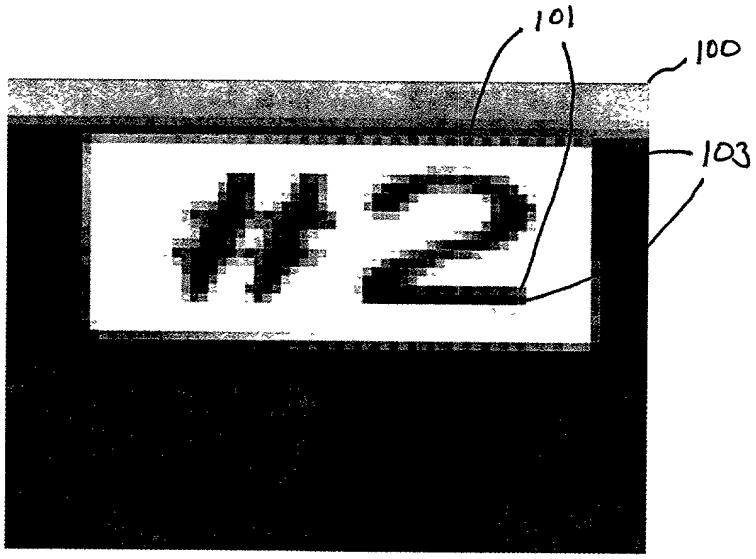

FIG. 1
(Prior Art)

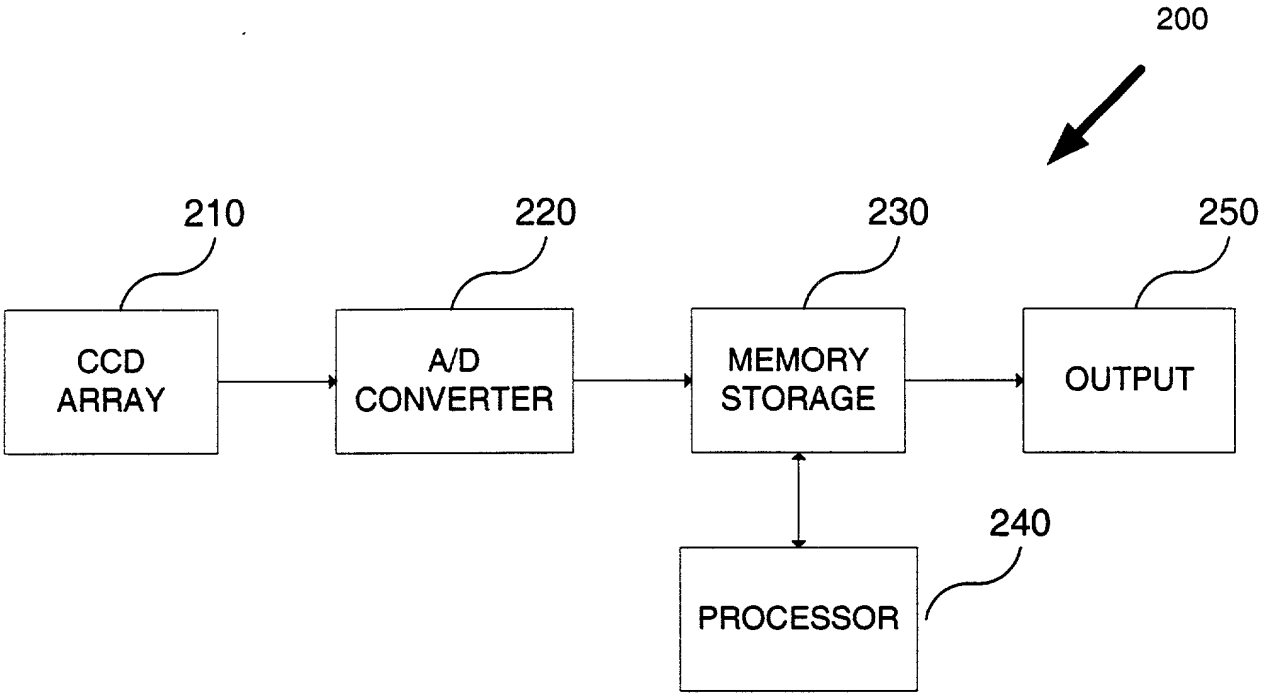
200
210
220
230
250
CCD ARRAY
A/D CONVERTER
MEMORY STORAGE
OUTPUT
240
PROCESSOR

FIG. 2

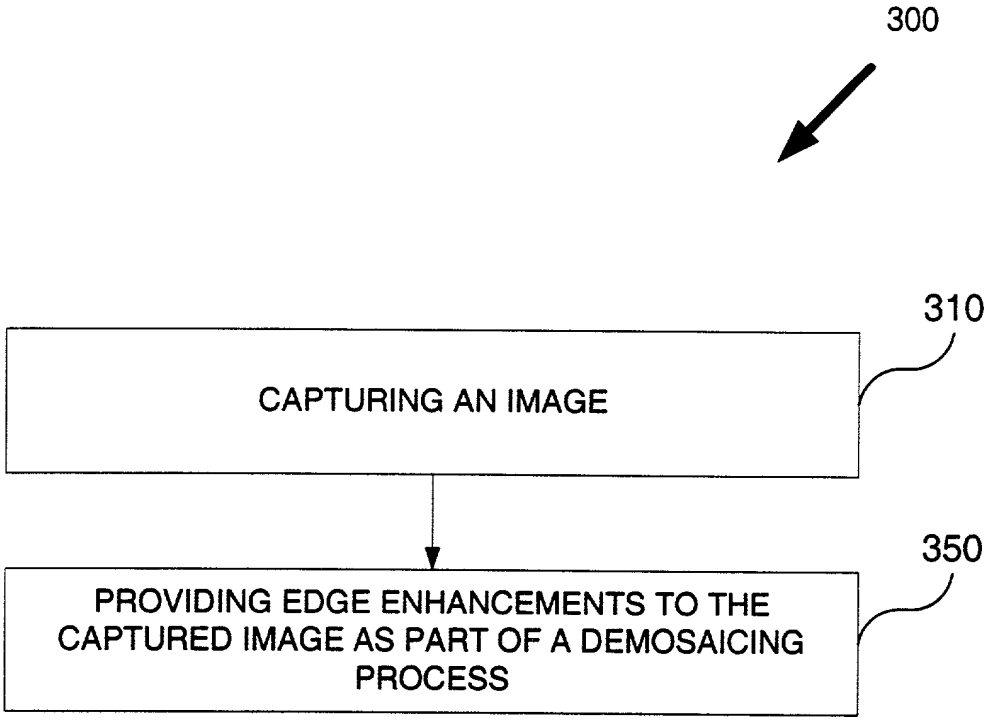
300
310
CAPTURING AN IMAGE
350
PROVIDING EDGE ENHANCEMENTS TO THE CAPTURED IMAGE AS PART OF A DEMOSAICING PROCESS

FIG. 3

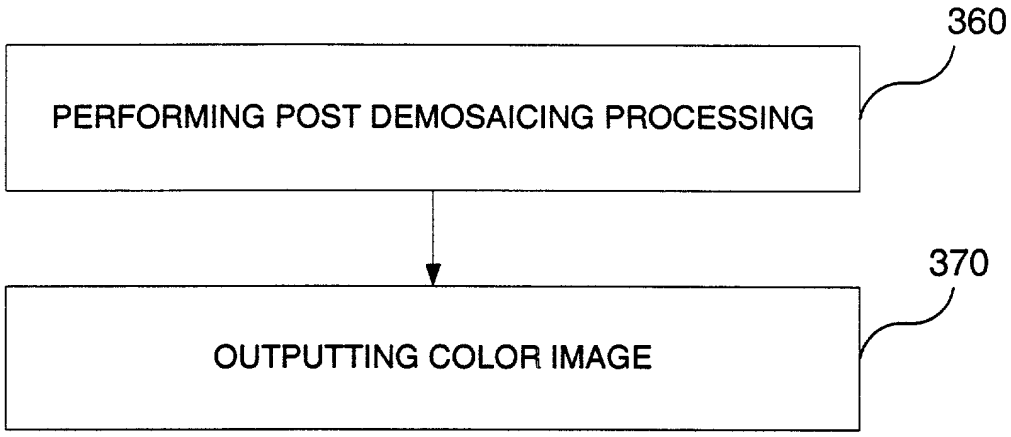
360
PERFORMING POST DEMOSAICING PROCESSING
370
OUTPUTTING COLOR IMAGE

FIG. 4

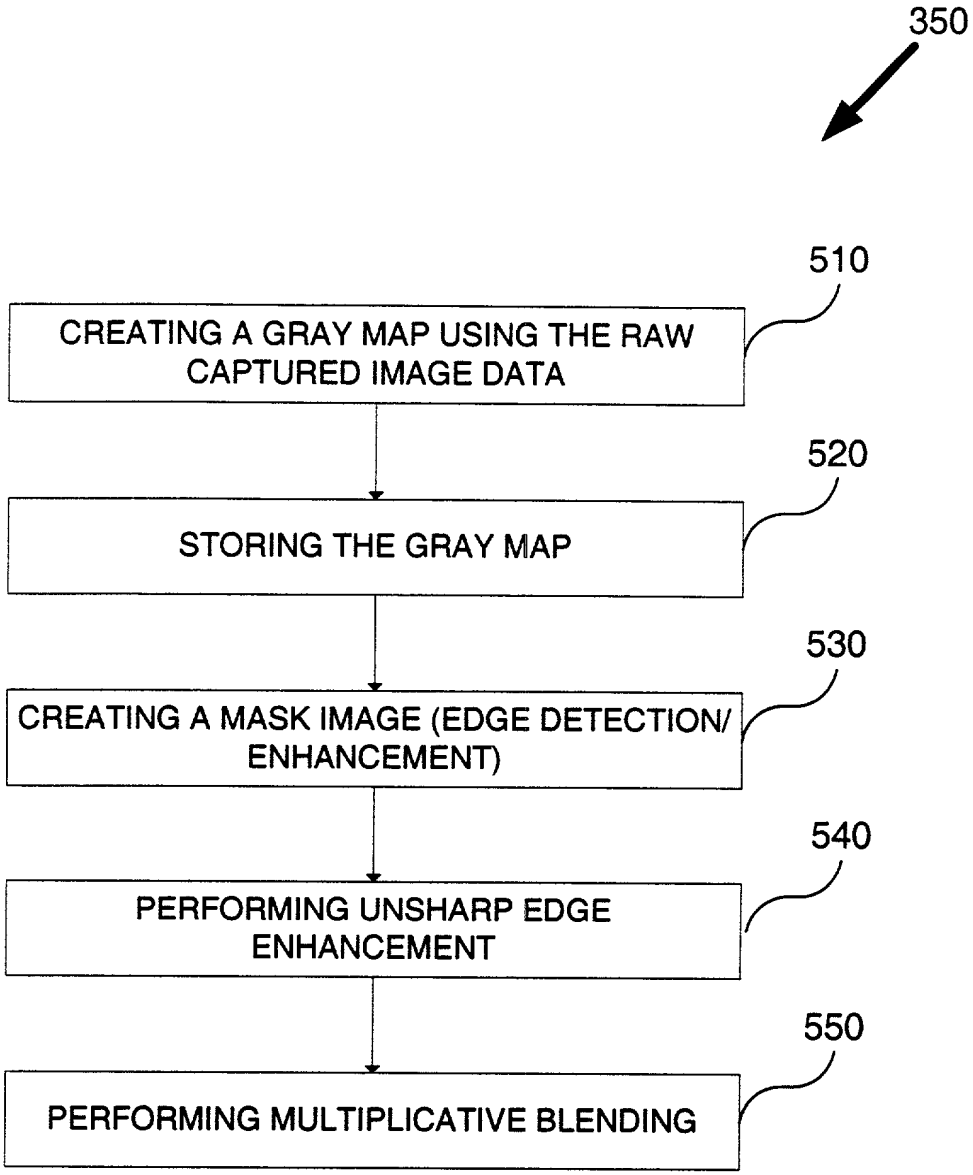
350
510
CREATING A GRAY MAP USING THE RAW CAPTURED IMAGE DATA
520
STORING THE GRAY MAP
530
CREATING A MASK IMAGE (EDGE DETECTION/ ENHANCEMENT)
540
PERFORMING UNSHARP EDGE ENHANCEMENT
550
PERFORMING MULTIPLICATIVE BLENDING

FIG. 5

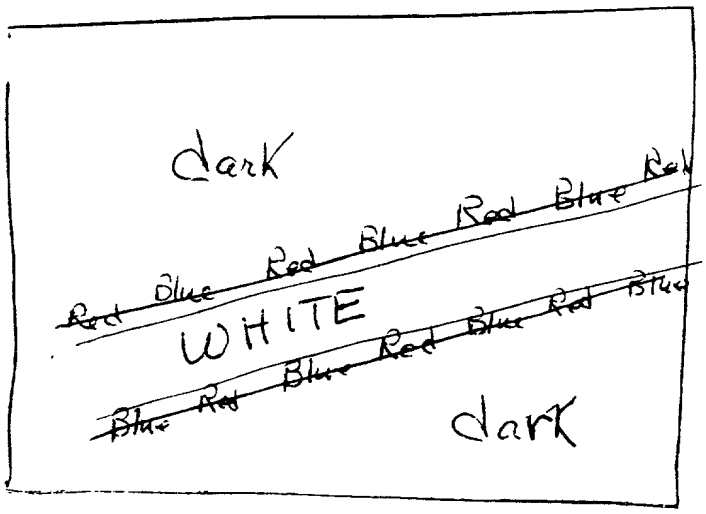

FIG. 6A

normal demosaic results of a high contrast line with FRINGE EFFECT

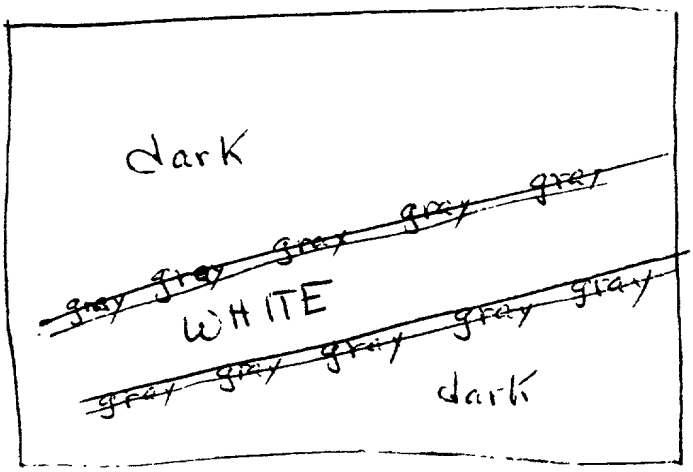

FIG.6B

FRINGE EFFECT removed showing achromatic edges

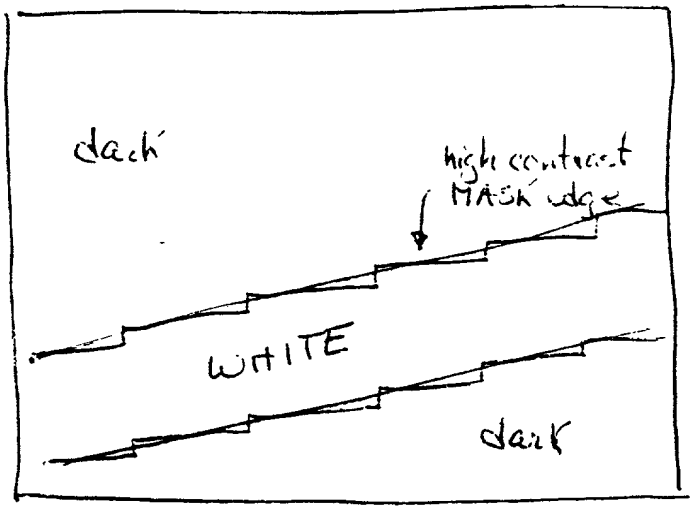

FIG.6C

Create MASK image from Fringe-corrected image

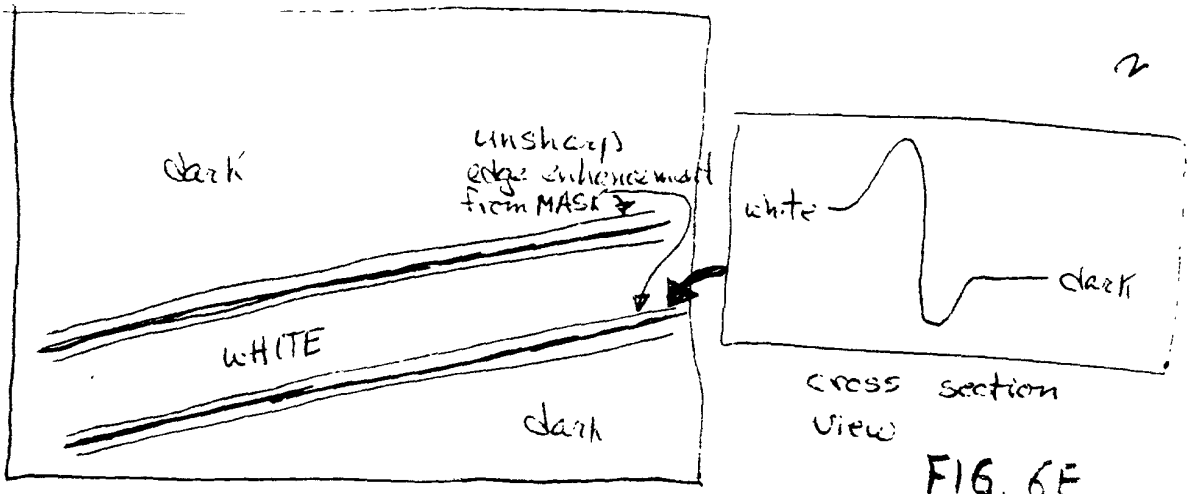

FIG. 6D

FIG. 6E

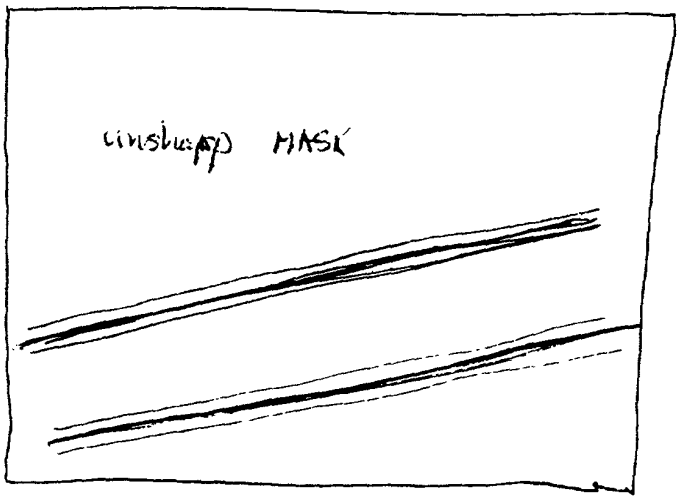

FIG. 6D

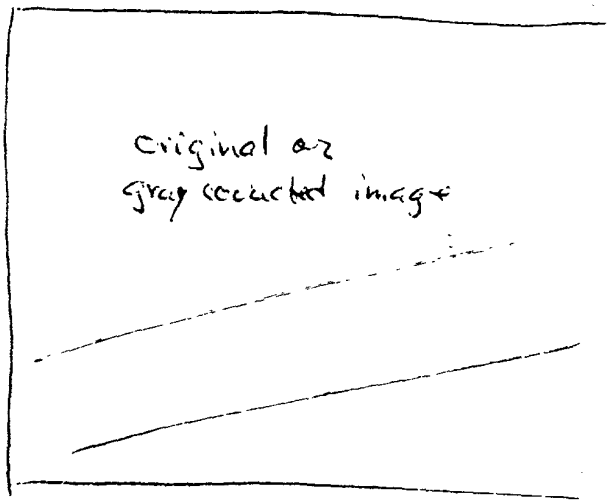

FIG 6A or 6B

multiplicative blend

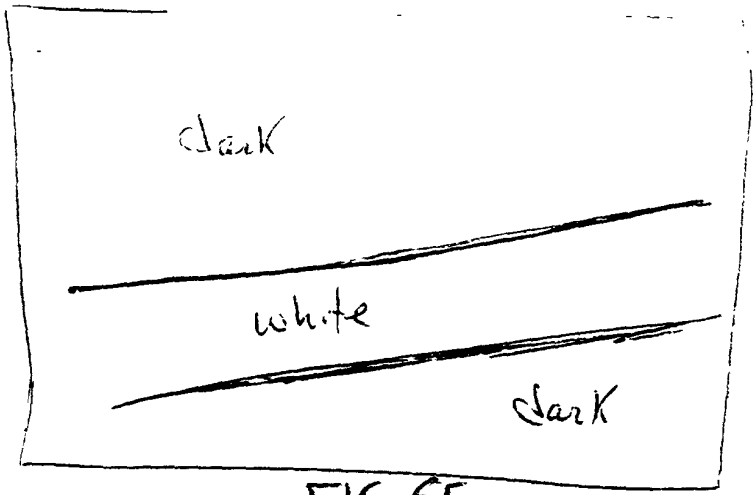

FIG 6F

Final Edge Enhanced image from Demosaic + Edge Enhancement Process

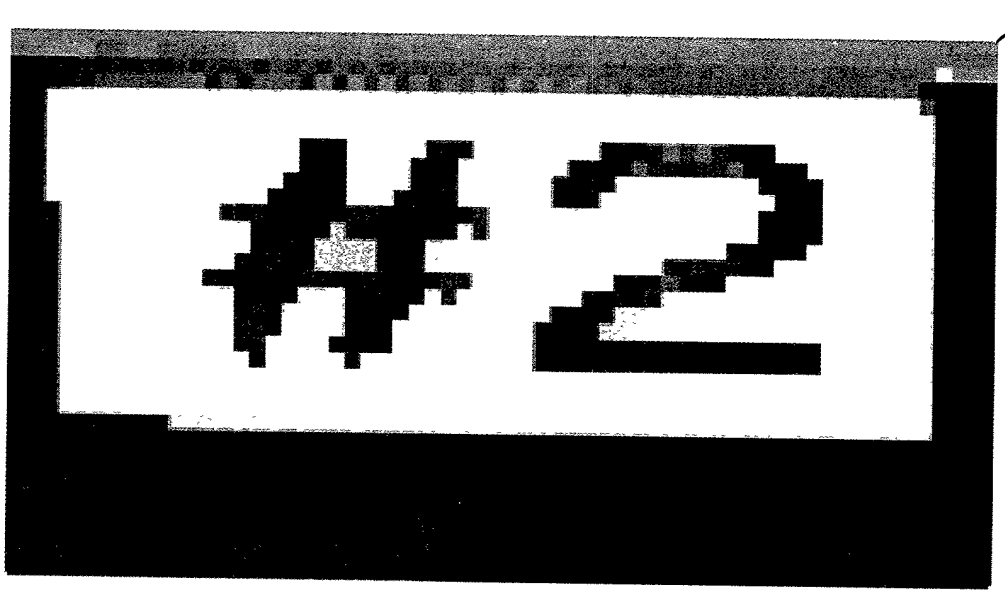

FIG. 6G

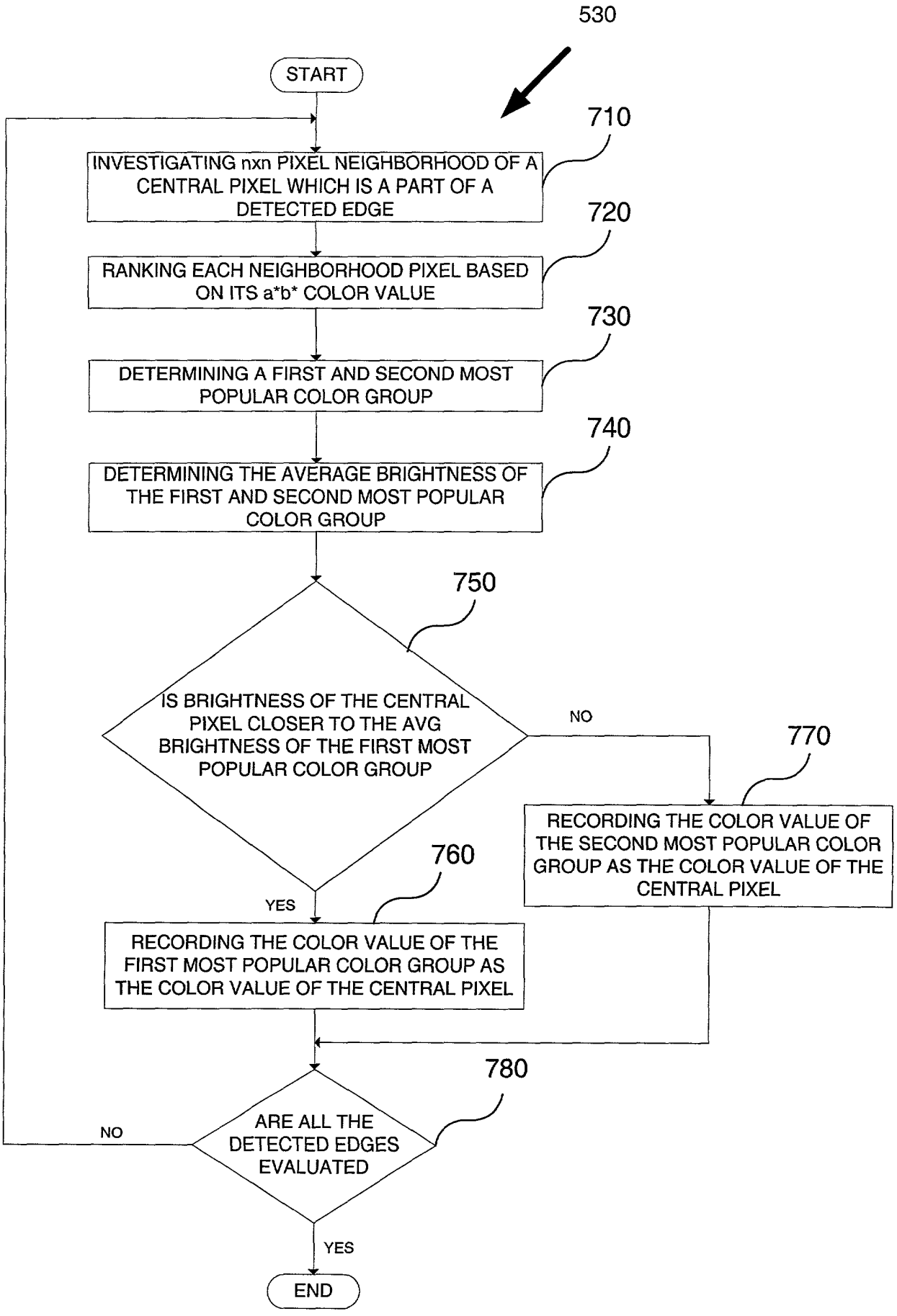
530
START
710
INVESTIGATING nxn PIXEL NEIGHBORHOOD OF A CENTRAL PIXEL WHICH IS A PART OF A DETECTED EDGE
720
RANKING EACH NEIGHBORHOOD PIXEL BASED ON ITS a*b* COLOR VALUE
730
DETERMINING A FIRST AND SECOND MOST POPULAR COLOR GROUP
740
DETERMINING THE AVERAGE BRIGHTNESS OF THE FIRST AND SECOND MOST POPULAR COLOR GROUP
750
IS BRIGHTNESS OF THE CENTRAL PIXEL CLOSER TO THE AVG BRIGHTNESS OF THE FIRST MOST POPULAR COLOR GROUP
NO
770
RECORDING THE COLOR VALUE OF THE SECOND MOST POPULAR COLOR GROUP AS THE COLOR VALUE OF THE CENTRAL PIXEL
YES
760
RECORDING THE COLOR VALUE OF THE FIRST MOST POPULAR COLOR GROUP AS THE COLOR VALUE OF THE CENTRAL PIXEL
780
ARE ALL THE DETECTED EDGES EVALUATED
NO
YES
END

FIG. 7

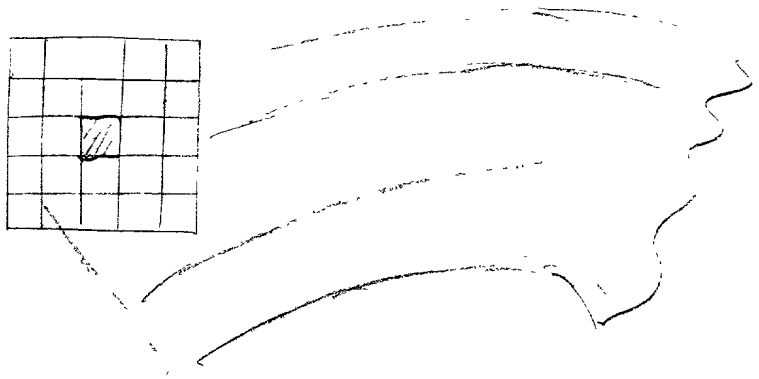

FIG. 8A

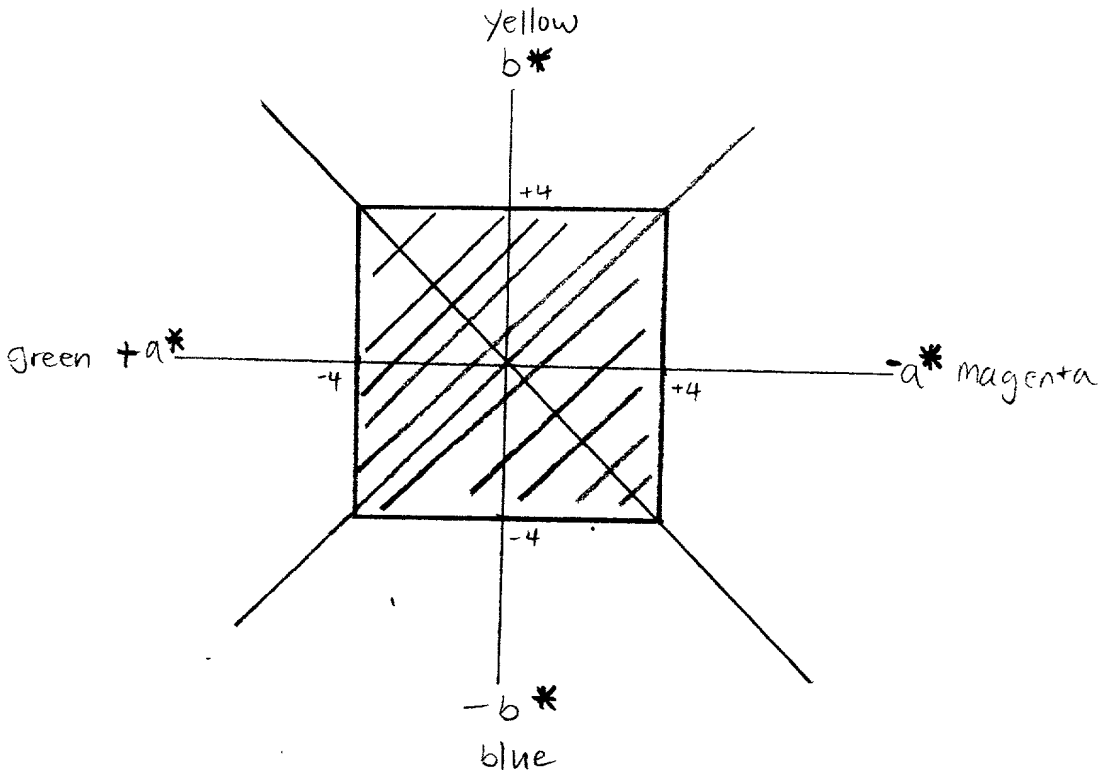

FIG. 8B

Attorney's Docket No.: 80398.P350 PATENT

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled
METHOD AND APPARATUS TO PROVIDE EDGE ENHANCEMENTS AS PART OF A DEMOSAICING PROCESS

the specification of which

_X_ is attached hereto.
___ was filed on (MM/DD/YYYY) _____ as
United States Application Number _____
or PCT International Application Number _____
and was amended on (MM/DD/YYYY) _____.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
Number	Country	(Foreign Filing Date - MM/DD/YYYY)	Yes	No
Number	Country	(Foreign Filing Date - MM/DD/YYYY)	Yes	No
Number	Country	(Foreign Filing Date - MM/DD/YYYY)	Yes	No

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below:

Application Number	(Filing Date – MM/DD/YYYY)
Application Number	(Filing Date – MM/DD/YYYY)

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Application Number	(Filing Date – MM/DD/YYYY)	Status -- patented, pending, abandoned
Application Number	(Filing Date – MM/DD/YYYY)	Status -- patented, pending, abandoned

I hereby appoint the persons listed on Appendix A hereto (which is incorporated by reference and a part of this document) as my respective patent attorneys and patent agents, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send correspondence to Maria E. Sobrino (Name of Attorney or Agent), BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, 12400 Wilshire Boulevard 7th Floor, Los Angeles, California 90025 and direct telephone calls to Maria E. Sobrino (Name of Attorney or Agent), (408) 720-8300.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of Sole/First Inventor Ted J. Cooper

Inventor's Signature Ted J. Cooper Date 24 Oct 2000

Residence Sunnyvale, California (City, State) Citizenship United States of America (Country)

Post Office Address 746 Silver Tip Way
Sunnyvale, California 94086

APPENDIX A

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APPENDIX B

Title 37, Code of Federal Regulations, Section 1.56
Duty to Disclose Information Material to Patentability

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclosure information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclosure all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) Prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) The closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made or record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application;

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.